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Specification & Statement of Work: Fabrication of the Core Motion Platform for the Target Assembly Station

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SPECIFICATION & STATEMENT OF WORK

Fabrication of the Core Motion Platform for the Target Assembly Station

ENGINEERING @ LLNL

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1 Introduction

This specification and statement of work is for the partial build of the target assembly station. The targets being assembled are described in a paper[1] that is included with the request for quotation. This document primarily describes the work to be done by the buyer (LLNL) and the seller in delivering what is termed the "core motion platform." The goal of the Target Fabrication Group at LLNL is to upgrade this machine over the next several years to produce a state-of-the-art target assembly station.

The next two sections further clarify the items that compose the core motion platform and the additional items needed to complete the assembly station. Remaining sections focus primarily on the core motion platform, including design information, performance requirements, acceptance testing, responsibilities, and deliverables.

1.1 Items in the Core Motion Platform

This section gives an overview of items in the core motion platform; later sections will cover items in much greater detail. The core motion platform consists of the controlled-axes (x-axis, y-axis, z-axis, lower spindle, and upper spindle) necessary to position and assemble target components, and a structure (a base and a column) for supporting the axes. The core motion platform also includes the controller for controlling the axes and a user interface for controlling the motion and displaying force data and position data.

1.2 Additional Items for the Assembly Station

A substantial portion of the design beyond the core motion platform is incomplete or only partially complete. The following items will likely be added to the system in the near future:

- Vibration isolators
- Additional compliance along the z-axis
- Vision systems (two cameras and a microscope) for providing visual feedback to the user
- Higher resolution force feedback
- Grounding hook for neutralizing static charges at the target components
- A glovebox for isolating hazardous materials
- Non-vision-based position feedback (e.g., using LVDTs or cap gauges to align the spindle axes) for higher accuracy

[1] R. L. Hibbard, et al., "Precision Manufacturing of Inertial Confinement Fusion Double Shell Laser Targets," 2003, UCRL-JC-153448.

2 Design Information

The machine configuration is shown in Figure 1 and described in more detail in the following subsections. This instrument will be used by a target assembler to assemble small complex targets. This process currently includes manually cleaning the targets and manually applying adhesives. Therefore, the assembler must have good access (visually and physically) to the target holding components that are attached to the spindle faces.

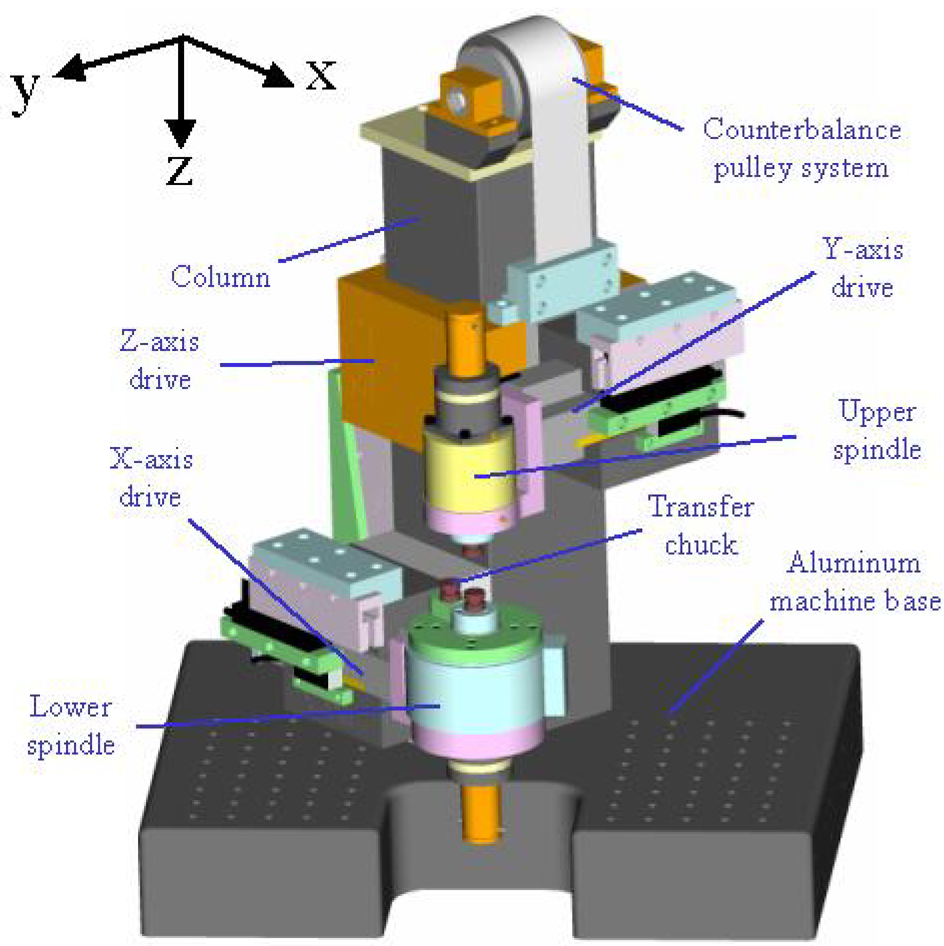

Figure 1: The core motion platform – conceptual CAD model

2.1 The Machine Base

The machine base is constructed of die-free, hard-anodized aluminum. The base supports the column, which holds all of the slides. The top of the base contains 2 grids (~5 holes by ~8 holes) of ¼-20 threaded holes – one grid on each side of the column as shown in Figure 1. The holes are spaced 1 inch apart. The bottom of the base is machined out to reduce weight (see Figure 2). Three sets of three ¼-20 holes are machined into the bottom of the base to accommodate the isolation and mounting hardware (see Figure 2). The center of gravity for the system should be kept as close as possible to the center of the triangle created by the three 3-hole patterns to increase stability. Eight ¼-20 holes are machined into each side (left and right side) of the base to provide additional mounting capability. The top and side walls of the base are a minimum of ½ inch thick. The hard anodizing takes place after the machining of all the holes. A drawing containing details of the ¼-20 threaded hole patterns on the bottom of the base and the sides of the base is included with the request for bid (AAA04-503292-AA).

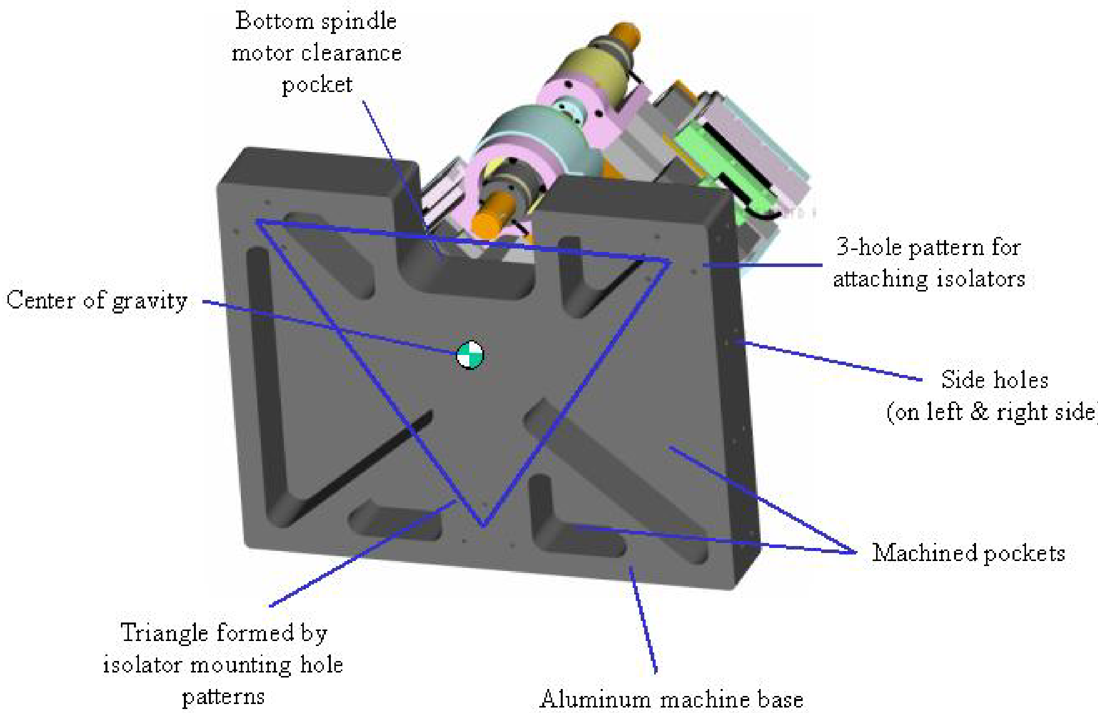

Figure 2: Bottom of the machine base

2.2 Column

The column is attached to the base. It provides a vertical mounting platform for supporting the slides. The column is rotated 45 degrees in the x-y plane relative to the machine base (see Figure 1). The bottom of the column supports the x-axis hardware. The column also acts as an air-bearing surface for the z-axis (located above the x-axis). The weight of the z-axis and the hardware attached to it are counterbalanced with a mass of stainless steel. The mass is located inside of the column. It is connected to the z-axis via a metal band and a pulley system (see Figure 1). The pulley system is attached to the top of the column. It uses seal-less un-lubricated stainless radial bearings (grade 5 or 7) to support the pulley.

2.3 Z Slide

The z-axis slide provides vertical motion for the upper spindle. It consists of an air bearing, linear motor, encoder, and scale. The air bearing is shielded to prevent the exiting air from interfering with the target assembly process. The z-axis holds the y-axis, which holds the upper spindle. The weight of the z-axis and the attached components are counterbalanced by a weight (see column description – section 2.2).

Figure 3 shows the software-stop range (it is shown between the two spindle faces) to be covered by the z slide. Hardware stops (mechanical stops) are required, and they must be at least 1 millimeter past the software stops. However, the hardware stops cannot allow more than 5 millimeters of travel beyond the software stop range. Choosing a practical homing position and method is the responsibility of the chosen vendor.

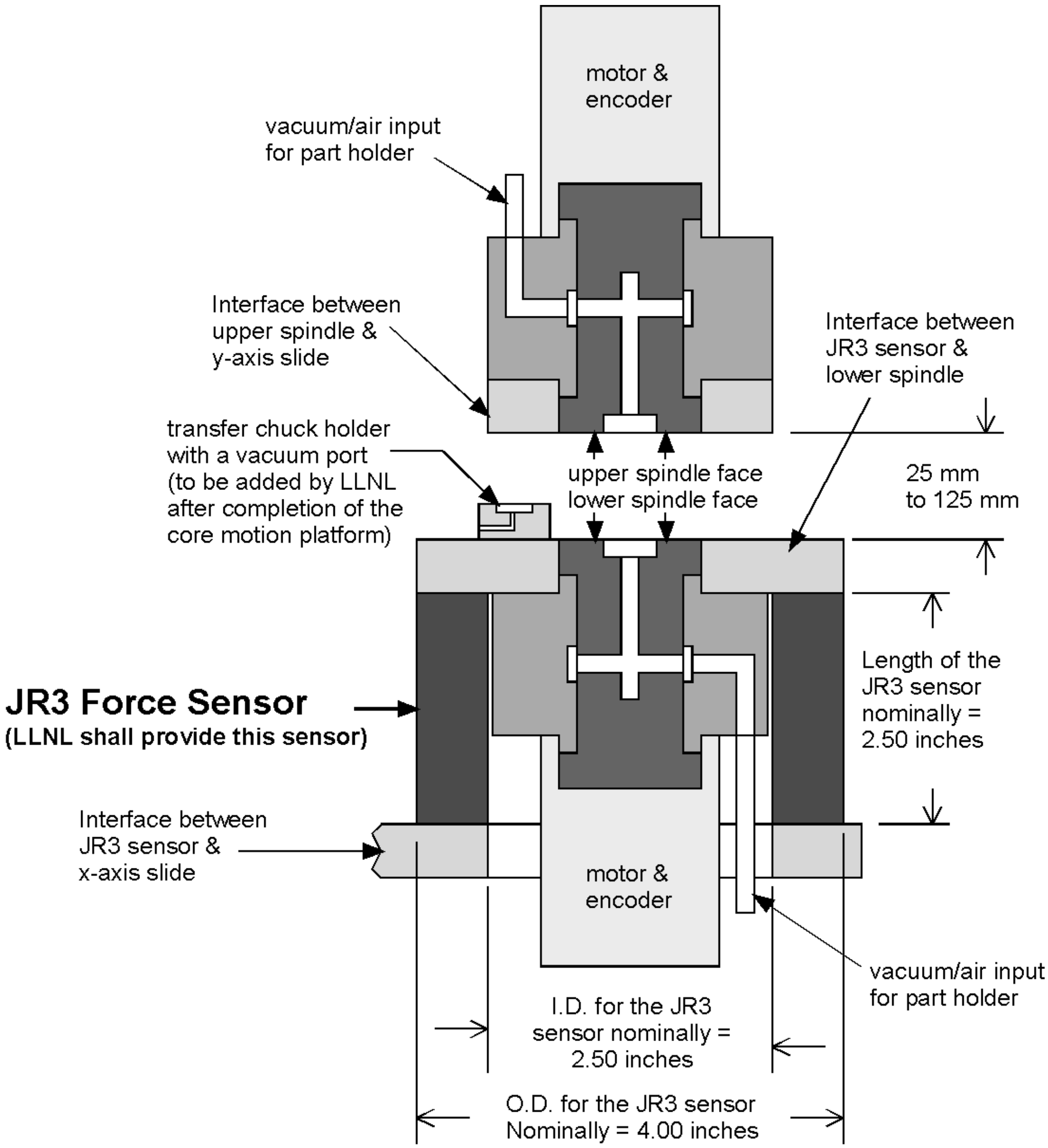

Figure 3: Lower and upper spindle illustration

2.4 X Slide

The x-axis slide provides motion in the horizontal plane for the lower spindle. It consists of an air bearing, linear motor, scale, and scale reader. The air bearing is shielded to prevent the exiting air from interfering with the target assembly process. The x-axis supports the lower spindle. The x-axis is attached to the column near the machine base. Figure 4 shows the software-stop range to be covered by the x and y slides. Hardware stops (mechanical stops) are required, and they must be at least 1 millimeter past the software stops. However, the hardware stops cannot allow more than 5 millimeters of travel beyond the software stop range.

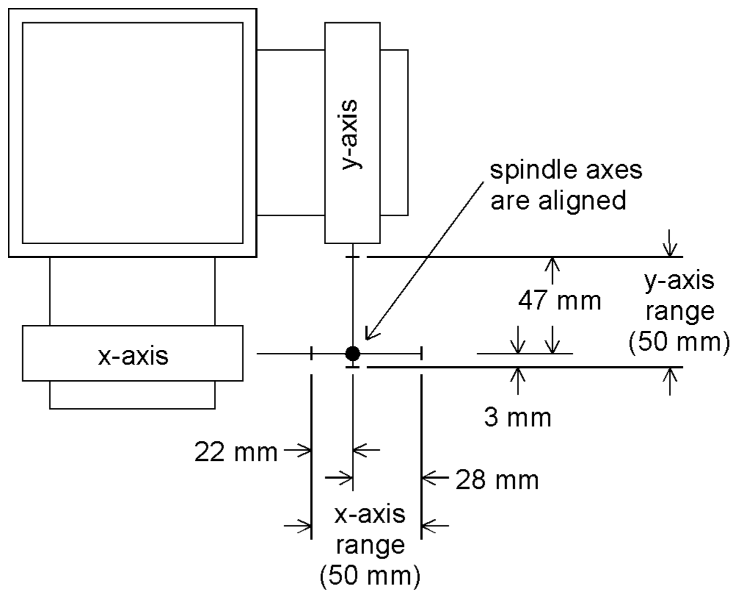

Figure 4: software-stop ranges for the x-axis and y-axis

2.5 Y Slide

The y-axis slide provides horizontal motion perpendicular to the x-axis motion for positioning the upper spindle. It consists of an air bearing, linear motor, encoder, and scale. The air bearing is shielded to prevent the exiting air from interfering with the target assembly process. The y-axis supports the upper spindle. The y-axis slide is attached to the z-axis slide. Figure 4 shows the software-stop range to be covered by the x and y slides. Hardware stops (mechanical stops) are required, and they must be at least 1 millimeter past the software stops. However, the hardware stops cannot allow more than 5 millimeters of travel beyond the software stop range.

2.6 Lower Spindle

The lower spindle provides rotary motion for target component assembly. Targets are attached to the spindle via an LLNL-installed chuck and chuck holder. The lower spindle is attached to the x-axis slide through a JR3 force sensor (LLNL will provide the JR3 force sensor to the chosen vendor). The non-rotating portion of the lower spindle also supports an LLNL-installed transfer chuck. The transfer chuck is located nominally one inch away in the x direction from the lower spindle axis (see Figure 1). The transfer chuck must be able to be positioned under the upper spindle's axis (part transfer mode). The chuck requires a vacuum/air line plumbed thought the spindle.

See Figure 3 for an illustration of the lower spindle hardware and its interfaces. See Drawing AAA04-503293-AA for details on the target holder interfaces. The lower and upper spindles must have the ability to synchronously rotate with each other per the specifications in Section 3.1.

2.7 Upper Spindle

The upper spindle provides rotary motion for target component assembly. Targets are attached to the spindle via an LLNL-installed chuck and chuck holder. The upper spindle is rigidly attached to the y-axis slide. The chuck requires a vacuum/air line plumbed through the spindle. See Figure 3 for an illustration of the upper spindle hardware and its interfaces. See Drawing AAA04-503294-AA for details on the target holder interface. The lower and upper spindles have the ability to synchronously rotate with each other per the specifications in Section 3.1.

2.8 JR3 Force/Moment Sensor

The force/moment sensor to be used was designed and fabricated by JR3 Inc of Woodland, California[2]. The sensor will be supplied by LLNL to the chosen vendor. The sensor is based on their standard sensor, but it has been altered to accommodate the air-bearing spindle (i.e., JR3 provided a 2.5 inch diameter hole in their sensor). The chosen vendor for the core motion platform shall work with the JR3 sensor hardware to ensure that all interfaces between the sensor and core motion platform are compatible. The dimensions for the modified JR3 sensor are shown in JR3's interface drawing (JR3 drawing number: 4910). It is known that the outside diameter of the sensor is nominally 4 inches; however, four screw heads and the connector protrude beyond the 4-inch diameter. The height of the unit is nominally 2.5 inches. The inside diameter is nominally 2.5 inches. The diameter of the air-bearing spindle that sits inside of the force sensor must be small enough to accommodate the small lateral movement of the sensor (movement will only occurs when forces are applied). Figure 3 illustrates the interfaces between the sensor and the core motion platform hardware.

2.9 Controller, Drives, and Sensors

All slides and spindles are controlled via a motion controller. The controller uses feedback from the scales/encoders to control the motion at the specified accuracy (see section 3.1 for performance specifications). The six analog outputs from the JR3 sensor are converted to digital signals via 16-Bit A/D converters. Figure 5 shows a schematic of the control system. The following controller components (manufactured by Delta-Tau) are recommended:

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[2] LLNL contact is Wayne Johnson at JR3: (530) 661-3677.

ITEM	QTY	Part	Description	Part Number
01	1	UMAC Turbo Controller	UMAC Turbo Controller with on-board 100Mbit Ethernet and USB2.0	3R0-603766-10x
02	1	ACC-R3	Integrated UMAC Rack with 18 slot backplane, 21 Slot Rack and Power Supply	584-604269-10x
03	2	ACC-24E2A	2-Axis Analog Axis Interface	3R0-603398-10x
04	1	ACC-24E2A, OPT-1A	Additional 2 Axis Analog Interface	301-603398-10x
05	2	ACC-28E	16 Bit A/D High Resolution Converter Board	3R0-603404-10x
06	2	ACC-28E, OPT-1	2 Additional On-Board 16 Bit A/D Converters	301-603404-OPT
07	1	ACC-65E	24In/24Out I/O Board Sourcing (recommended)	3R0-603575-10x

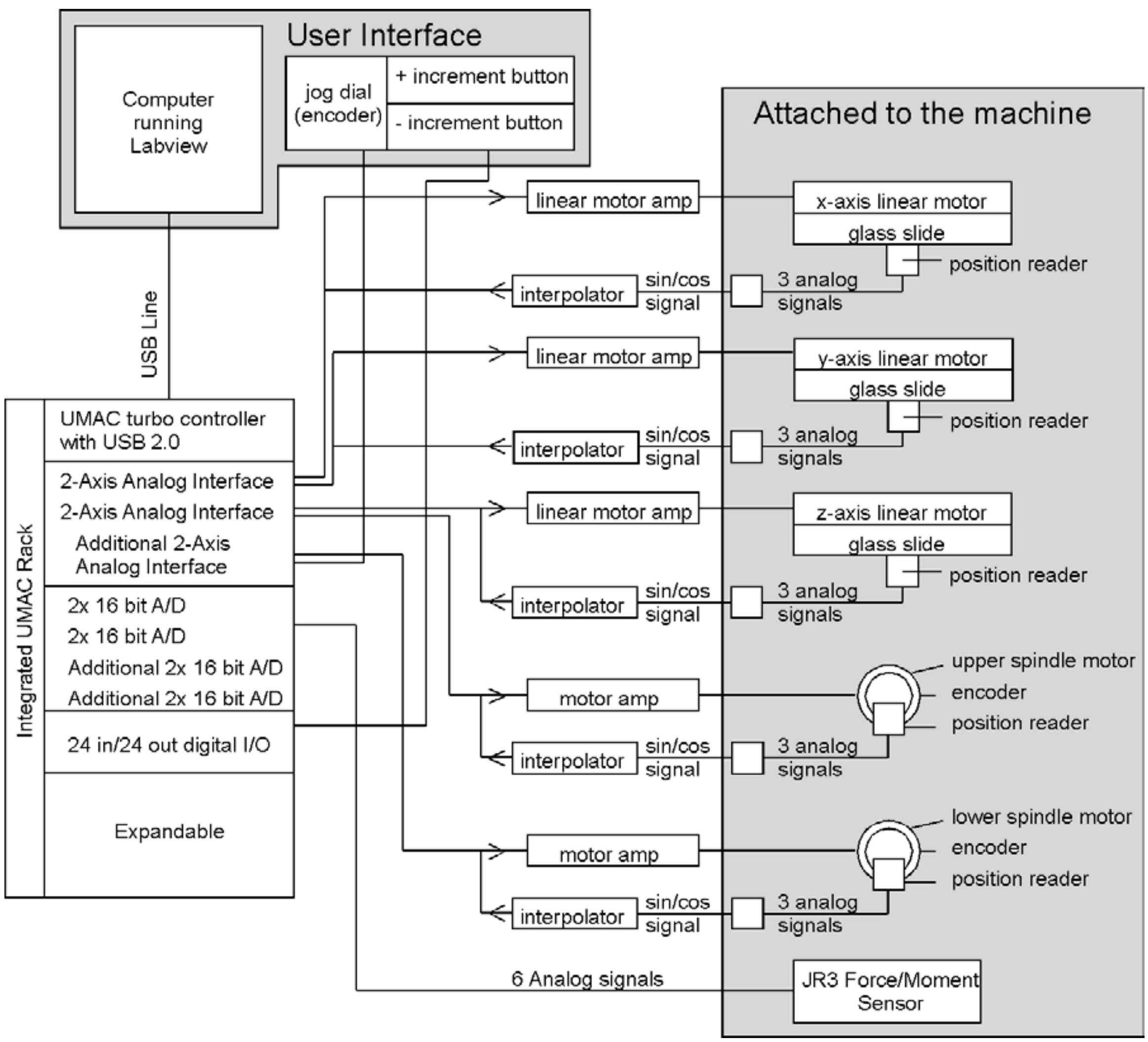

Figure 5: Schematic for the control system

An additional card with two 16 Bit A/D inputs (for a total of eight) is also recommended for control system tuning (it is shown in Figure 5). The 24-I/O digital card receives the increment button input. The jog dial is read by the sixth analog interface.

The position sensors (scales/encoders) must provide high-resolution feedback. To achieve this, analog to digital interpolators (versus direct digital quadrature) are recommended. Components with similar resolutions and capabilities of the Heidenhain scales & encoders given here are recommended:

- LIP 481, Heidenhain Glass Scale, 70mm, +/-0.5um accuracy, 2um/cycle, Heidenhain read head for LIP 481 included, match with scale
- ERP880, Heidenhain Angular encoder, 180,000 ele. cycle/rev
- IBV660B, Heidenhain up to 400x interpolation module (in-line module – one per axis)

2.10 User Interface

The user interface will allow the user to drive the slides and will display both drive position and JR3 force data for the user via a computer screen. The user interface shall use Labview to display the data and send commands to the controller. The user interface shall have the following minimum capabilities:

- Drive selection (x-axis, y-axis, z-axis, lower spindle, and upper spindle).
- Mechanical increment buttons (forward and reverse) and a mechanical jog dial (one increment of motion for every click of the jog dial with 50 to 200 clicks per revolution)
- A scale selector for the axes (1x, 10x, 100x, 1kx, 10kx)
- A least increment motion for the linear axes of 100 nanometers
- A least increment motion for the rotary axes of 100 micro-radians
- A synchronous spindle capability that makes one spindle (slave) synchronously follow the other (master) spindle

3 Performance Requirements

The core motion platform shall meet the performance requirements list below. They include mechanical, electrical, and cleanliness specifications.

3.1 Mechanical

This section documents the mechanical performance requirements. These include stage positioning requirements, size limitations, weight limitations, vision system clearances, and interfaces between LLNL hardware and the core motion platform.

3.1.1 Positioning requirements

The core motion platform shall meet the following positioning requirements:

Core Motion System	Requirement
X, Y position accuracy	1 um
X, Y position least increment repeatable motion over the full range	0.1 um
X, Y range	≥ 50 mm
X, Y stationary stability	+/- 25 nm
Z position accuracy	1 um
Z position least increment repeatable motion over the full range	0.1 um
Z range	≥ 100 mm
Z stationay stability	+/- 25 nm
Upper and lower spindle range	+/- 370 deg
Least increment repeatable motion	100 micro-rad
Axial error motion	0.05 um
Radial error motion	0.05 um
Rotational resolution	1 micro-rad
Axis alignment between the two spindles	50 micro-rad
Synchronous rotation - following error	10 micro-rad

3.1.2 Size

The core motion platform should be as small as possible to make it both quasi-portable and capable of being put into a glovebox (for future applications). The height from the bottom of the machine base to the top of the pulley system shall not exceed 24 inches. The width of the core motion platform shall not exceed 22 inches. The depth of the core motion platform shall not exceed 18 inches.

3.1.3 Weight

The core motion platform will likely be moved several times a year. To minimize complications, the weight of the core motion platform shall be kept under 150 pounds[3].

3.1.4 Vision System Clearance

Two cameras and a microscope will be added to the core motion platform to aid the assembler. Line of sight for those vision systems shall not be interfered with

[3] Based on the LLNL conceptual CAD model (Figure 1), LLNL estimates that the core motion platform should weight approximately 135 pounds; a contingency of 10% was added to the maximum weight constraint.

by the core motion platform hardware. Figures 6 and 7 show the locations of the two cameras. Figure 8 gives the basic dimensions of the vision systems and their position relative to the bottom spindle face. The microscope will be directly in front of the core motion platform. It will be attached to a movable arm.

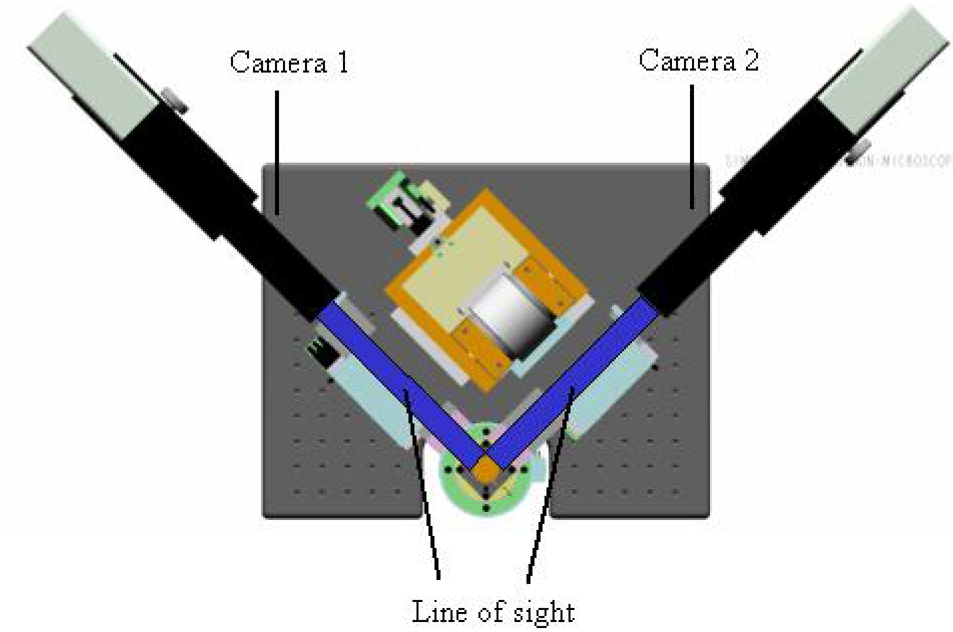

Figure 6: Top View showing the positional relationship between the cameras and the core motion platform

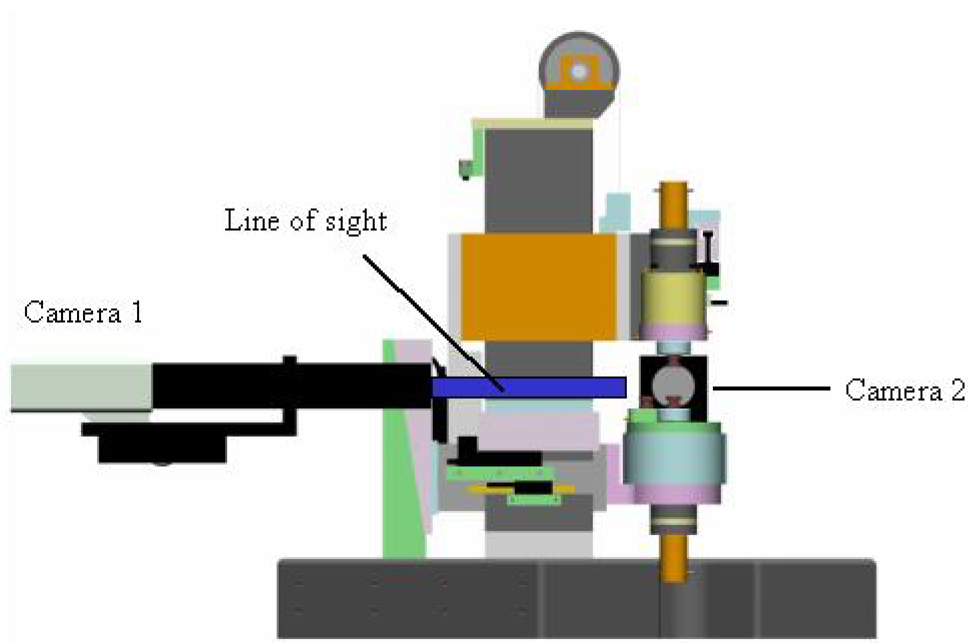

Figure 7: Horizontal view (rotated 45 degrees from the front view) showing the positional relationship between the cameras and the core motion platform

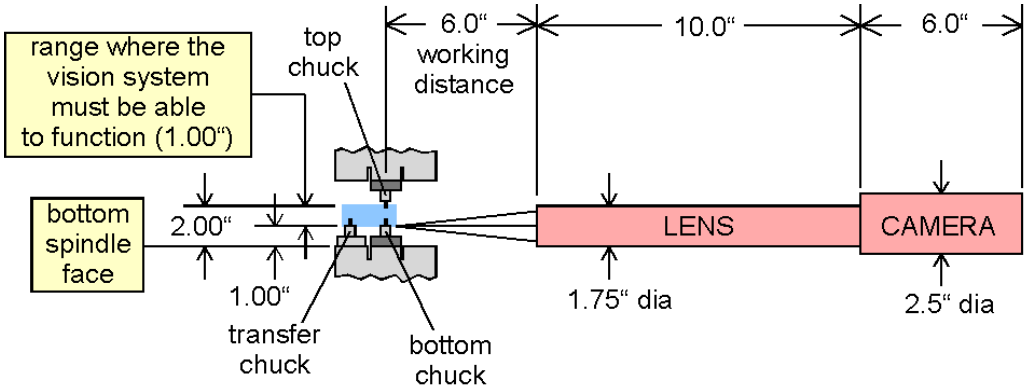

Figure 8: Basic dimensions of the vision systems

3.1.5 Interfaces between LLNL hardware and the Core Motion Platform

The following interfaces shall be designed as shown in the referenced drawings:

- The bottom hole patterns in the machine base for mounting the core motion platform (AAA04-503292-AA)
- The side hole patterns in the machine base for mounting hardware (AAA04-503292-AA)
- The transfer chuck interface on the lower spindle (AAA04-503293-AA)
- The chuck holder interface on both spindles (AAA-04-503294-AA)

The drawings will be sent with the request for quotation.

3.2 Electrical

The following codes, standards, polices, and procedures shall be followed:

– **National Fire Protection Association (NFPA 79),** *Electrical Standards for Industrial Machinery, 2002 Edition*. NFPA is an International Codes and Standards Organization based in Quincy, MA, (800) 344-3555

– **National Fire Protection Association (NFPA 70),** *National Electrical Code, 2002 Edition*. NFPA is an International Codes and Standards Organization based in Quincy, MA, (800) 344-3555

– **Underwriters Laboratory Incorporated (UL508),** *Safety for Industrial Control Equipment, 17th Edition*. UL is an independent, product-safety testing and certification organization based in Northbrook, IL, (847) 272-8800

– **Underwriters Laboratory Incorporated (UL508A),** *Safety for Industrial Control Panels, 1st Edition*. UL is an independent, product-safety testing and certification organization based in Northbrook, IL, (847) 272-8800

– **DOE/UC/LLNL, Environmental, Safety, and Health (ES&H Part 16),** *Electrical, Revision 1*. The ES&H manual contains general requirements for all Laboratory work involving the use of electrical equipment and systems.

3.3 Cleanliness

The assembly station will be used in a clean room in the future. To ensure that the assembly station is not a major contaminant contributor while in the clean room, the following cleanliness requirements on metals, finishes, machining fluids, and cleaning procedures shall be followed.

3.3.1 Unacceptable Metals

No steels shall be used except for stainless steels. No cast aluminum shall be used. Wrought aluminum materials are acceptable (e.g., 6061-T6).

3.3.2 Unacceptable Finishes

No surfaces shall be painted. Only die-free hard anodizing (MIL-A-8625, Type III, class I) shall be used on aluminum.

3.3.3 Acceptable Machining Fluids

Only the cutting fluids and tapping fluids listed in section 3.12 of MEL98-001-OH ("Fabrication of NIF Laser Components") shall be used.

3.3.4 Material Cleaning Procedures

All machined components shall be cleaned in accordance with MEL99-009-OE ("Gross Cleaning of NIF Components and Structures"). Section 9 covers cleaning of aluminum, and section 8 covers cleaning of stainless steel.

4 Acceptance Testing

Final acceptance of the machine system will require compliance of the performance requirements given in section 3. The measurement procedures are outlined in the following subsections. Where appropriate, the test should follow the following standard:

- Axes of Rotation - Methods for Specifying and Testing
Document Number: ASME B89.3.4M-1985 (R1992)
American Society of Mechanical Engineers
01-Jan-1985

4.1 Least Increment Motion

4.1.1 Procedures

The least increment motion in the x, y, and z directions are to be measured using cap gauges or LVDT's. See Figure 9 for an illustration of test.

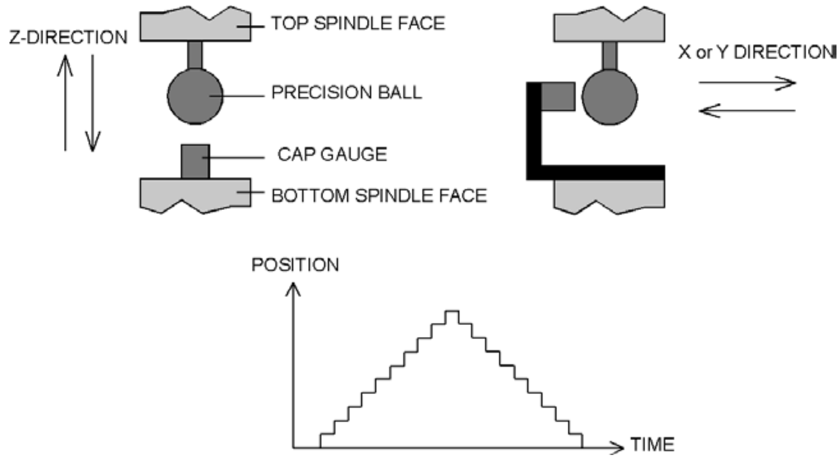

Figure 9: Least increment motion test

4.1.2 Machine set up

A ball is to be placed in the upper spindle. The lower spindle supports a cap gauge or LVDT.

4.1.3 Measurements

After setting up the x-axis measurement, move the x-axis by ten least increments. Return back to the starting position using least increments. Repeat the test for the other two directions. Also, measure the axial error motion for both spindles using the z-axis increment test hardware.

4.2 Axial Error

4.2.1 Procedures

Measure the axial error of the spindles while, individually rotating them through a full revolution. Use the z-axis increment test setup to perform the test.

4.2.2 Machine set up

Use the setup from the z-axis increment test.

4.2.3 Measurements

Measure the axial error of each spindle while individually rotating them through a full revolution.

4.3 Spindle Axes Alignment

4.3.1 Procedures

Measure the error between the spindle axes using a double-ball setup and two cap gauges or LVDTs. See Figure 10 for an illustration of the test.

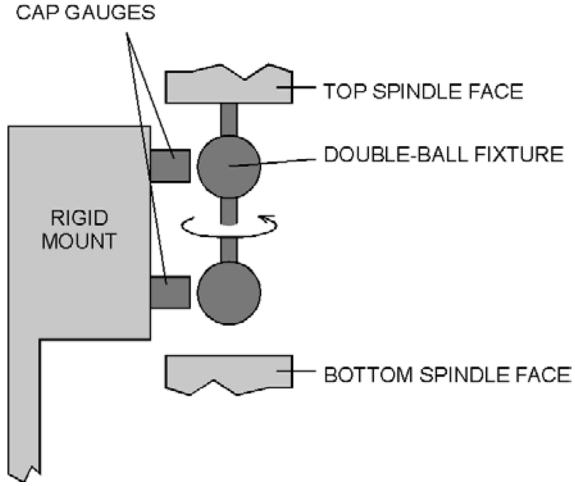

Figure 10: Spindle axes alignment test

4.3.2 Machine set up

The double-ball fixture is attached to the spindles. The cap gauges or LVDTs are rigidly mounted to the machine base.

4.3.3 Measurements

With the double-ball fixture attached to the upper spindle, rotate the upper spindle through 360 degrees and record the cap gauge output in the x-axis direction. Perform the same measurement in the y-axis direction. Attach the double-ball fixture to the bottom spindle and repeat the x-axis and y-axis measurements. Note, these tests will also determine radial error motion for both spindles.

4.4 Synchronous Test for the Spindles

4.4.1 Procedures

Measure the synchronous following error between the two spindles over a full revolution using a precision flat, a cap gauge (or LVDT), and mounting hardware.

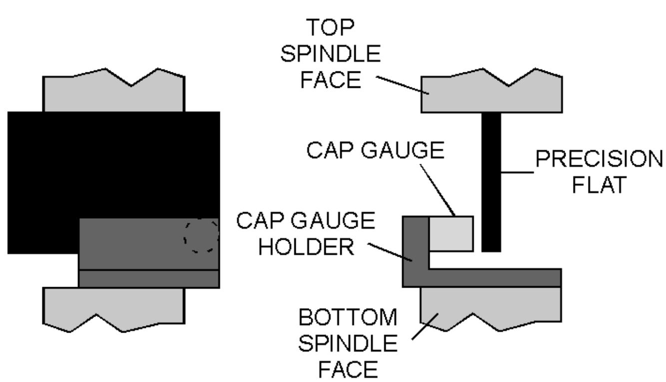

Figure 11: synchronous rotation test setup

4.4.2 Machine set up

Attach the precision flat to the top spindle face as shown in Figure 11. Attach the cap gauge to the bottom spindle near the precision flat, but off the spindle axes by a minimum 0.25 inches.

4.4.3 Measurements

With the testing hardware in place as described in subsection 4.4.2, synchronously rotate the two spindles through one full revolution while recording the change in displacement measured by the cap gauge.

5 Responsibilities

The following describes the responsibilities of the seller and the buyer.

5.1 Items to be supplied by seller

Except for the LLNL supplied JR3 force/moment sensor, the seller shall furnish all materials, equipment, and personnel that are required to fabricate, assemble, and deliver the machine outlined in section 2.

5.1.1 Materials and equipment

The seller shall provide a machine system built as described in Section 2 and must meet the machine specification requirements listed in section 3.

5.1.2 Inspection and testing

The seller can provide inspection and testing equipment in accordance with section 3. LLNL shall bring inspection equipment for the compliance test if the seller requests it.

5.1.3 Documentation

The seller shall provide inspection and test reports. The seller shall provide all Labview codes created for running the assembly station.

5.1.4 Transportation

The seller shall be responsible for packing and shipping the machine listed in section 2.

5.2 Items to be supplied by LLNL

LLNL shall supply the JR3 force/moment sensor with the interface drawing and manuals, conceptual drawings of the core motion platform, LLNL cleanliness documents, LLNL electrical requirements, and a paper describing the manufacturing process for a double-shell target.

5.2.1 LLNL drawing information

The following drawings show the desired configuration of the core motion platform.

AAA04-503292-AA	Conceptual assembly drawing of the core motion platform
AAA04-503293-AA	Lower spindle subassembly drawing for the core motion platform
AAA04-503294-AA	Upper spindle subassembly drawing for the core motion platform

The following drawings are included as references:

AAA00-107082	Vacuum puck
AAA00-107083	Holder, Workpiece (referenced by AAA04-503293-AA)
AAA00-107084	Holder, Assembly

5.2.2 LLNL Cleanliness Documents

Two documents are included that relate to cleanliness. One covers gross cleaning of materials:

"Gross Cleaning of NIF Components and Structures," MEL99-009-OE, NIF5004297_OE99009.doc version 3.1,

and the other document covers acceptable cutting and tapping fluids for machined components:

"Fabrication of NIF Laser Components and Structures," MEL98-001-OH, NIF5001252_OH98001.doc version 2.

5.2.3 LLNL Electrical Documents

The following included document relates to electrical requirements for machines built at or for LLNL: "DOE/UC/LLNL, Environmental, Safety, and Health (ES&H Part 16), *Electrical, Revision 1*." The ES&H manual contains general requirements for all Laboratory work involving the use of electrical equipment and systems.

6 Deliverables

The following deliverables are required for completion of the core motion platform.

6.1 Detailed Design Review

The seller shall give a detailed design review of the core motion platform design. It shall cover all of the areas presented in this document. The seller can come to LLNL to give the review or LLNL can come to their facility for the review.

6.2 Construction of Subassemblies

Completion of all of the subassemblies (x-axis sub assembly, y-axis sub assembly, z-axis sub assembly, upper spindle assembly, lower spindle assembly, and the base/column subassembly) represents a deliverable. For the linear slides the subassembly includes the air bearing, linear motor, scale, scale reader, and mechanical stops. For the spindle axes, the subassemblies include the rotary air bearing, motor, encoder, and encoder reader.

6.3 Procurement and delivery of controller hardware

Procurement by the chosen vendor and delivery of the controller hardware to the chosen vendor represents a deliverable.

6.4 Assembly of the Mechanical System

Complete assembly of the mechanical systems (assembly of the subassemblies) and the counter weight hardware represents a deliverable.

6.5 Complete integration, Inspection, and Delivery of the Core Motion Platform

The final deliverable is the complete integration of the controller, user interface system, and the mechanical system. This system must pass the acceptance test.